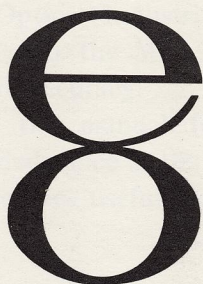




A PROGRAM
FOR
BLACKBODY RADIATION
CALCULATIONS

II

Planck's Law Programs
for the
Texas Instruments model SR-52
programmable calculator



prepared by Ray Chandos

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INTRODUCTION

This booklet includes 2 programs for the Texas Instruments Model SR-52 programmable calculator. These programs transfer the calculation capability of the Electro Optical Industries Inc. blackbody radiation sliderule to the Model SR-52 but with 5 significant figure accuracy.

A copy of the manual for the blackbody sliderule is included since it defines all terms and equations and provides useful examples of the use of the equations.

PROGRAM TITLE: BLACKBODY RADIATION SLIDERULE

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PROGRAM DESCRIPTION, EQUATIONS, VARIABLES:

Planck's expression for hemispherical blackbody flux density radiated in the wavelength interval λ to $\lambda+d\lambda$ is

$$H_{\lambda} = \frac{c_1}{\lambda^5} \cdot \frac{1}{e^{c_2/\lambda T} - 1} \quad [\text{W/cm}^2\text{-}\mu\text{m}]$$

where T = blackbody temperature (Kelvins)

$$c_1 = 37415 \text{ W-}\mu\text{m}^4/\text{cm}^2$$

$$c_2 = 14388 \text{ }\mu\text{m-K.}$$

The corresponding expression for photon output is

$$Q_{\lambda} = \frac{c_1'}{\lambda^4} \cdot \frac{1}{e^{c_2/\lambda T} - 1} \quad [\text{photons/sec-cm}^2\text{-}\mu\text{m}]$$

where $c_1' = 1.88365 \times 10^{23} \mu\text{m}^3/\text{sec-cm}^2$.

These programs compute

$$H_{\lambda}, Q_{\lambda}, \int_0^{\lambda} H_{\lambda} d\lambda, \int_0^{\lambda} Q_{\lambda} d\lambda, \int_{\lambda}^{\infty} H_{\lambda} d\lambda,$$

$$\int_{\lambda}^{\infty} Q_{\lambda} d\lambda \text{ given } \lambda \text{ and } T, H_{0-\infty} \equiv \int_0^{\infty} H_{\lambda} d\lambda,$$

$$Q_{0-\infty} \equiv \int_0^{\infty} Q_{\lambda} d\lambda \text{ given } T, \text{ as well as}$$

$$T = t_c + 273.15 = 5/9 (t_f - 32) + 273.15 \text{ given either } t_c \text{ (Celsius temperature) or } t_f \text{ (Fahrenheit temperature).}$$

TITLE: BLACKBODY RADIATION SLIDERULE I (Energy)

		◀A▶ BLACKBODY RADIATION SLIDERULE I	
$H_{\lambda} (W/cm^2 \mu m)$	$H_{0-\infty} (W/cm^2)$	$\int H_{\lambda} d\lambda (W/cm^2)$	
$\lambda (\mu m)$	$T (K)$	$t_c (^{\circ}C) \rightarrow T$	$t_f (^{\circ}F) \rightarrow T$

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Enter program (A and B)			
2	To calculate H_{λ}			
	input wavelength λ	$\lambda (\mu m)$	A	
	blackbody temperature T,	$T (K)$ Note 1	B	
	compute H_{λ}		*A'	$H_{\lambda} (W/cm^2 - \mu m)$
3	To calculate $H_{0-\infty}$			
	input T	$T (K)$ Note 1	A	
	compute $H_{0-\infty}$		*B'	$H_{0-\infty} (W/cm^2)$
4	To calculate $\int H_{\lambda} d\lambda$			
	input λ	$\lambda (\mu m)$	A	
	input T	$T (K)$ Note 1	B	
	compute answer		*C'	$\int H_{\lambda} d\lambda (W/cm^2)$
	$= \int_0^{\lambda} H_{\lambda} d\lambda$ if pos.			
	$= \lambda \int_{-\infty}^{\infty} H_{\lambda} d\lambda$ if neg.			

NOTES:	
1	Temperature may be entered in $^{\circ}C$ or $^{\circ}F$ by pressing C or D, respectively, instead of B.
2	λ and T are stored in memory on entry and need not be re-entered for subsequent calculations.

LOC	CODE	KEY	LOC	CODE	KEY	LOC	CODE	KEY	LABELS
⁰⁰⁰ ₁₁₂	46	*LBL		01	1		05	5	A λ (μm)
	11	A		04	4		46	*LBL	B T (K)
	42	STO	⁰⁴⁰ ₁₅₂	03	3		57	*fix	C $t_c(^{\circ}\text{C}) \rightarrow T$
	00	0		08	8		52	EE	D $t_f(^{\circ}\text{C}) \rightarrow T$
	01	1		08	8	⁰⁸⁰ ₁₉₂	57	*fix	E
⁰⁰⁵ ₁₁₇	56	*rtn		55	\div		04	4	A' $H_{\lambda} (W/\text{cm}^2 \cdot \mu\text{m})$
	46	*LBL		43	RCL		95	=	B' $H_{0-\infty} (W/\text{cm}^2)$
	12	B	⁰⁴⁵ ₁₅₇	00	0		56	*rtn	C' $\int H_{\lambda} d\lambda (W/\text{cm}^2)$
	42	STO		01	1		46	*LBL	D'
	00	0		55	\div	⁰⁸⁵ ₁₉₇	17	*B'	E'
⁰¹⁰ ₁₂₂	02	2		43	RCL		43	RCL	REGISTERS
	56	*rtn		00	0		00	0	00
	46	*LBL	⁰⁵⁰ ₁₆₂	02	2		02	2	01 λ
	13	C		95	=		45	γ^x	02 T
	85	+		42	STO	⁰⁹⁰ ₂₀₂	04	4	03 used
⁰¹⁵ ₁₂₇	02	2		00	0		55	\div	04 used
	07	7		03	3		01	1	05 used
	03	3	⁰⁵⁵ ₁₆₇	56	*rtn		07	7	06 used
	93	.		46	*LBL		06	6	07
	01	1		16	*A'	⁰⁹⁵ ₂₀₇	03	3	08
⁰²⁰ ₁₃₂	05	5		15	E		07	7	09
	95	=		22	INV		52	EE	10
	41	GTO	⁰⁶⁰ ₁₇₂	23	$\ln x$		07	7	11
	12	B		75	—		41	GTO	12
	46	*LBL		01	1	¹⁰⁰ ₂₁₂	57	*fix	13
⁰²⁵ ₁₃₇	14	D		95	=		46	*LBL	14
	75	—		20	*1/x		18	*C'	15
	03	3	⁰⁶⁵ ₁₇₇	65	x		00	0	16
	02	2		03	3		42	STO	17
	95	=		07	7	¹⁰⁵ ₂₁₇	00	0	18
⁰³⁰ ₁₄₂	65	X		04	4		04	4	19
	05	5		01	1		01	1	FLAGS
	55	\div	⁰⁷⁰ ₁₈₂	05	5		42	STO	0
	09	9		55	\div		00	0	1
	41	GTO		43	RCL	¹¹⁰ ₂₂₂	05	5	2
⁰³⁵ ₁₄₇	13	C		00	0		15	E	3
	46	*LBL		01	1				4
	15	E	⁰⁷⁵ ₁₈₇	45	γ^x				

LOC	CODE	KEY	LOC	CODE	KEY	LOC	CODE	KEY	LABELS
000 112	75	—	0	65	X		75	—	A
	93	.		43	RCL		43	RCL	B
	08	8	040 152	00	0		00	0	C
	95	=		05	5		04	4	D
	80	*if pos		95	=	080 192	55	÷	E
005 117	44	SUM		65	X		01	1	A'
	10	*E'		53	(		44	SUM	B'
	07	7	045 157	42	STO		00	0	C'
	55	÷		00	0		05	5	D'
	08	8		06	6	085 197	52	EE	E'
010 122	04	4		65	X		06	6	REGISTERS
	75	—		53	(		95	=	00
	10	*E'	050 162	42	STO		80	*if pos	01
	05	5		85	+		44	SUM	02
	95	=		03	3	090 202	43	RCL	03
015 127	55	÷		54	)		00	0	04
	06	6		85	+		04	4	05
	00	0	055 167	06	6		65	X	06
	85	+		54	)		01	1	07
	10	*E'		85	+	095 207	05	5	08
020 132	04	4		06	6		55	÷	09
	55	÷		95	=		59	*π	10
	08	8	060 172	55	÷		45	γ ^x	11
	75	—		43	RCL		04	4	12
	10	*E'		00	0	100 212	65	X	13
025 137	03	3		05	5		41	GTO	14
	55	÷		45	γ ^x		17	*B'	15
	03	3	065 177	04	4		46	*LBL	16
	95	=		55	÷		10	*E'	17
	41	GTO		43	RCL	105 217	43	RCL	18
030 142	02	2		00	0		00	0	19
	00	0		06	6		03	3	FLAGS
	05	5	070 182	22	INV		45	γ ^x	0
	46	*LBL		23	ln x		56	*rtn	1
	44	SUM		95	=	110 222			2
035 147	43	RCL		44	SUM				3
	00	0		00	0				4
	03	3	075 187	04	4				

TITLE: BLACKBODY RADIATION SLIDERULE II (Photons)

		◀A▶ BLACKBODY RADIATION SLIDERULE II	
$Q_{\lambda} \left(\frac{\text{photons}}{\text{sec-cm}^2 \mu\text{m}} \right)$	$Q_{0-\infty} \left(\frac{\text{photons}}{\text{sec-cm}^2} \right)$	$\int Q_{\lambda} d\lambda \left(\frac{\text{photons}}{\text{sec-cm}^2} \right)$	
$\lambda (\mu\text{m})$	T (K)	$t_c (^{\circ}\text{C}) \rightarrow T$	$t_f (^{\circ}\text{F}) \rightarrow T$

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Enter program (A and B)			
2	To calculate Q_{λ}			
	input wavelength λ	$\lambda (\mu\text{m})$	A	
	blackbody temperature T	T (K) Note 1	B	
	compute Q_{λ}		*A'	$Q_{\lambda} \left(\frac{\text{photons}}{\text{sec-cm}^2 \mu\text{m}} \right)$
3	To calculate $Q_{0-\infty}$			
	input T	T (K) Note 1	A	
	compute $Q_{0-\infty}$		*B'	$Q_{0-\infty} \left(\frac{\text{photons}}{\text{sec-cm}^2} \right)$
4	To calculate $\int Q_{\lambda} d\lambda$			
	input λ	$\lambda (\mu\text{m})$	A	
	input T	T (K) Note 1	B	
	compute answer		*C'	$\int Q_{\lambda} d\lambda \left(\frac{\text{photons}}{\text{sec-cm}^2} \right)$
	$= \int_0^{\lambda} Q_{\lambda} d\lambda$ if pos.			
	$= -\lambda \int_{\lambda}^{\infty} Q_{\lambda} d\lambda$ if neg.			

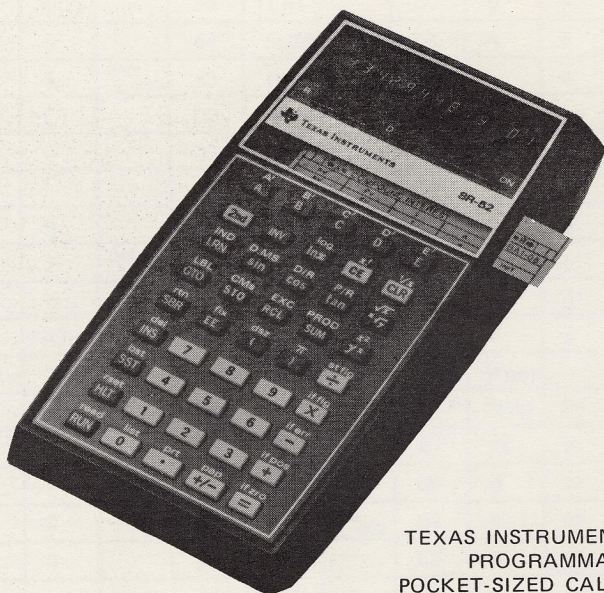
NOTES:

- 1 Temperature may be entered in $^{\circ}\text{C}$ or $^{\circ}\text{F}$ by pressing C or D, respectively, instead of B.
- 2 λ and T are stored in memory on entry and need not be re-entered for subsequent calculations.

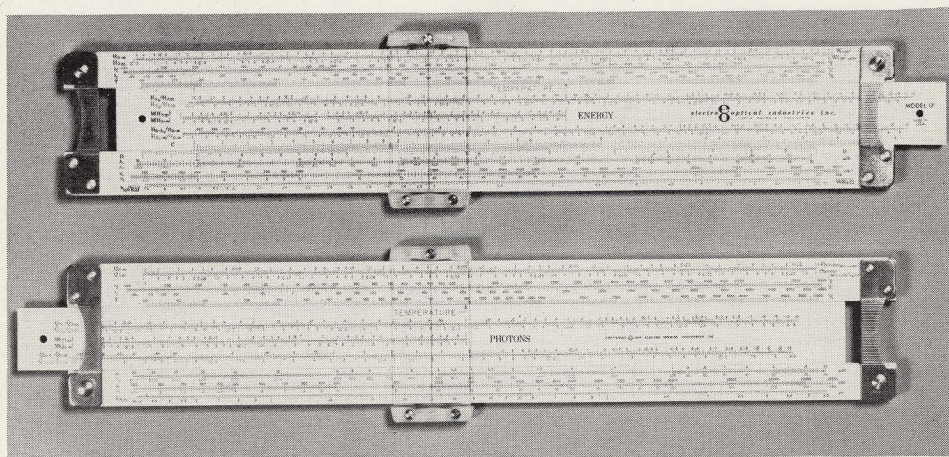
LOC	CODE	KEY	LOC	CODE	KEY	LOC	CODE	KEY	LABELS
000 112	46	*LBL		01	1		43	RCL	A $\lambda(\mu\text{m})$
	11	A		04	4		00	0	B T(K)
	42	STO	040 152	03	3		01	1	C $t_c(^{\circ}\text{C}) \rightarrow T$
	00	0		08	8		45	γ^x	D $t_f(^{\circ}\text{F}) \rightarrow T$
	01	1		08	8	080 192	04	4	E
005 117	56	*rtn		55	\div		46	*LBL	A' $Q_{\lambda} \left(\frac{\text{photons}}{\text{sec-cm}^2 \cdot \mu\text{m}} \right)$
	46	*LBL		43	RCL		57	*fix	B' $Q_{0-\infty} \left(\frac{\text{photons}}{\text{sec-cm}^2} \right)$
	12	B	045 157	00	0		52	EE	C' $\int Q_{\lambda} d\lambda \left(\frac{\text{photons}}{\text{sec-cm}^2} \right)$
	42	STO		01	1		57	*fix	D'
	00	0		55	\div	085 197	04	4	E'
010 122	02	2		43	RCL		95	=	REGISTERS
	56	*rtn		00	0		56	*rtn	00
	46	*LBL	050 162	02	2		46	*LBL	01 λ
	13	C		95	=		17	*B'	02 T
	85	+		42	STO	090 202	43	RCL	03 used
015 127	02	2		00	0		00	0	04 used
	07	7		03	3		02	2	05 used
	03	3	055 167	56	*rtn		45	γ^x	06 used
	93	.		46	*LBL		03	3	07
	01	1		16	*A'	095 207	65	X	08
020 132	05	5		15	E		01	1	09
	95	=		22	INV		05	5	10
	41	GTO	060 172	23	$\ln x$		02	2	11
	12	B		75	-		00	0	12
	46	*LBL		01	1	100 212	04	4	13
025 137	14	D		95	=		52	EE	14
	75	-		20	*1/x		07	7	15
	03	3	065 177	65	X		41	GTO	16
	02	2		01	1		57	*fix	17
	95	=		08	8	105 217	46	*LBL	18
030 142	65	X		08	8		18	*C'	19
	05	5		03	3		00	0	FLAGS
	55	\div	070 182	06	6		42	STO	0
	09	9		05	5		00	0	1
	41	GTO		52	EE	110 222	04	4	2
035 147	13	C		01	1		01	1	3
	46	*LBL		08	8				4
	15	E	075 187	55	\div				

LOC	CODE	KEY	LOC	CODE	KEY	LOC	CODE	KEY	LABELS
⁰⁰⁰ ₁₁₂	42	STO		46	*LBL		00	0	A
	00	0		44	SUM		04	4	B
	05	5	⁰⁴⁰ ₁₅₂	43	RCL		55	÷	C
	15	E		00	0		01	1	D
	75	—		03	3	⁰⁸⁰ ₁₉₂	44	SUM	E
⁰⁰⁵ ₁₁₇	93	.		65	X		00	0	A'
	08	8		43	RCL		05	5	B'
	07	7	⁰⁴⁵ ₁₅₇	00	0		52	EE	C'
	95	=		05	5		06	6	D'
	80	*if pos		95	=	⁰⁸⁵ ₁₉₇	95	=	E'
⁰¹⁰ ₁₂₂	44	SUM		42	STO		80	*if pos	REGISTERS
	10	*E'		00	0		44	SUM	00
	06	6	⁰⁵⁰ ₁₆₂	06	6		43	RCL	01
	55	÷		85	+		00	0	02
	09	9		01	1	⁰⁹⁰ ₂₀₂	04	4	03
⁰¹⁵ ₁₂₇	00	0		95	=		55	÷	04
	75	—		40	*x ²		02	2	05
	10	*E'	⁰⁵⁵ ₁₆₇	85	+		93	.	06
	04	4		01	1		04	4	07
	95	=		95	=	⁰⁹⁵ ₂₀₇	00	0	08
⁰²⁰ ₁₃₂	55	÷		55	÷		04	4	09
	04	4		43	RCL		01	1	10
	08	8	⁰⁶⁰ ₁₇₂	00	0		02	2	11
	85	+		05	5		65	X	12
	10	*E'		45	y ^x	¹⁰⁰ ₂₁₂	41	GTO	13
⁰²⁵ ₁₃₇	03	3		03	3		17	*B'	14
	55	÷		55	÷		46	*LBL	15
	06	6	⁰⁶⁵ ₁₇₇	43	RCL		10	*E'	16
	75	—		00	0		43	RCL	17
	10	*E'		06	6	¹⁰⁵ ₂₁₇	00	0	18
⁰³⁰ ₁₄₂	02	2		22	INV		03	3	19
	55	÷		23	ln x		45	y ^x	10 FLAGS
	02	2	⁰⁷⁰ ₁₈₂	95	=		56	*rtn	0
	95	=		44	SUM				1
	41	GTO		00	0	¹¹⁰ ₂₂₂			2
⁰³⁵ ₁₄₇	02	2		04	4				3
	00	0		75	—				4
	03	3	⁰⁷⁵ ₁₈₇	43	RCL				

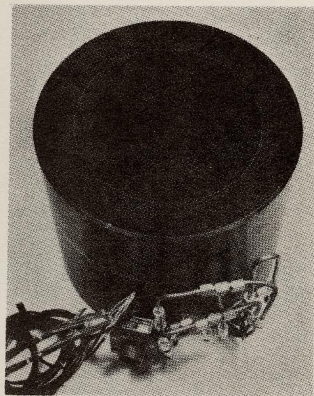
NOTES:



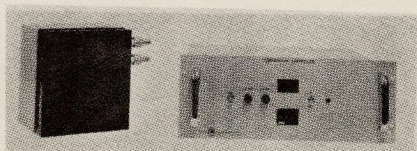
TEXAS INSTRUMENTS' SR-52
PROGRAMMABLE
POCKET-SIZED CALCULATOR



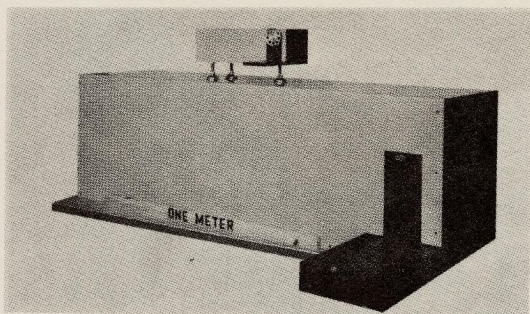
ELECTRO OPTICAL INDUSTRIES'
MODEL 17
RADIATION SLIDERULE



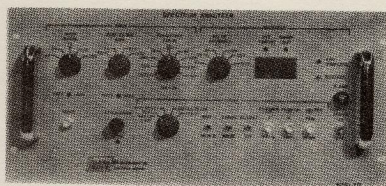
**CRYOGENIC VACUUM
BLACKBODIES**



**THERMOELECTRIC
DIFFERENTIAL
BLACKBODIES**

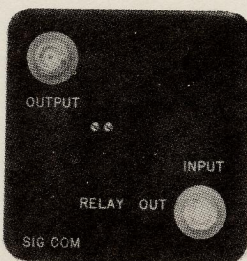


COLLIMATORS
1 inch to 12 inches

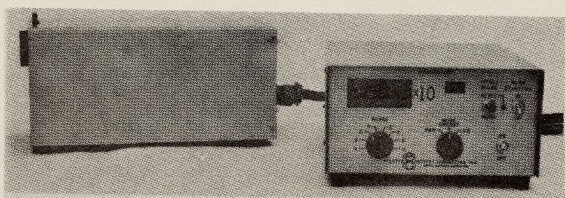


SPECTRUM ANALYZER
1Hz to 50kHz

PREAMPLIFIER
low impedance



SPECTRORADIOMETERS





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